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APPLICATION NUMBER: *60/564,143*
FILING DATE: *April 21, 2004*
RELATED PCT APPLICATION NUMBER: *PCT/US05/13561*

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15992 U.S. PTO

22151 U.S. PTO
60/564143

PTO/SB/16 (01-04)
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. ER 898 ~~333~~ 333934 US

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Jorge	Sanchez-Olea	15655 Oakstand Road Poway CA, 92064

Additional inventors are being named on the ______ *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Laser Performance Compensation Through Signal Processing Methods

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☐ Customer Number: ______

OR

☑ Firm or Individual Name	CEYX Technologies				
Address	4903 Morena Blvd.				
Address	Ste 1216				
City	San Diego	State	CA	Zip	92117
Country		Telephone	858-270-2399	Fax	

ENCLOSED APPLICATION PARTS (*check all that apply*)

☑ Specification *Number of Pages* 9

☑ Drawing(s) *Number of Sheets* 6

☐ Application Data Sheet. See 37 CFR 1.76

☐ CD(s), Number ______

☐ Other (specify) ______

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☑ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees.

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FILING FEE Amount ($): $80.00

The Invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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Respectfully submitted,

SIGNATURE Jorge Sanchez-Olea

Date 4/20/2004

TYPED or PRINTED NAME Jorge Sanchez-Olea

REGISTRATION NO. ______
(if appropriate)
Docket Number: ______

TELEPHONE 858-748-6746

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Additional Page

PTO/SB/16 (08-03)
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CEYX®
Technologies

Jorge P. Sanchez
President & Chief Technology Officer

4903 Morena Blvd. • Ste 1216 • San Diego, CA 92117
Phone / 858 270-2399 • Fax / 619 839-3765
email: jorgesanchez@ceyx.com

LASER SYSTEM PERFORMANCE COMPENSATION THROUGH SIGNAL PROCESSING METHODS

REFERENCES

This provisional patent application is a continuation of the US patent that will result from National Phase of pending Application number PCT/US03/00463 titled "Apparatus and Method for Measurement of Dynamic Laser Signals" filed on January 8, 2003, which is an application based on Provisional Application SN: 60/346,728 titled "Continuous Laser Performance Compensation" filed on January 8, 2002.

Furthermore, this provisional application is a continuation of the US patent that will result from National Phase of pending Application number PCT/US03/01032 titled "Laser Temperature Performance Compensation" filed on January 14, 2003, which is an application based on Provisional Application SN: 60/348,967 titled "Laser Power Sensing Methods" filed on January 14, 2002. PCT/US03/01032 is a continuation in part of US patent application US 09/724,692 now US 6,629,638 titled "Electro Optic System Controller and Method of Operation". US 6,629,638 patent in turn is a continuation in part of patent US 6, 446,867 titled "Electro-Optic Interface System and Method of Operation" filed on December 24, 1999.

BACKGROUND

Field of the Invention

The invention relates to methods and circuits used to perform compensation for aging, temperature, linearity and other types of compensation to control performance of a laser or another light emitting device. The method and circuits can be used to compensate for

aging, temperature and other degradation of other components in a system that employs a light emitting device.

Methods and circuits in this provisional application will be presented as they apply to lasers. However similar methods and circuits will also apply to other embodiments that include different type of light emitting devices such as LEDs, lamps, and fluorescent lamps.

Description of related technology

Lasers exhibit significant variations in their performance characteristics. Particularly, as lasers age and with temperature variations, they will substantially degrade in performance. An example of the variation of lasers is shown in figure 1. The graph illustrates laser light power versus laser current. Characteristic 101 corresponds to the laser characteristic for temperature T1 or for an initial age of the laser; characteristic 102 is the laser characteristic for temperature T2 or for an aged laser. The control of the laser is set so that a given amount of light power is obtained with characteristic 101. If the characteristic then changes to characteristic 102 then the incorrect amount of light power will be obtained. The Laser Control System Block Diagram is shown in Figure 2. A typical system will consist of a Digital Controller 213, a Driver 202 containing a Bias Current Generator 203 along with a Modulation Current Generator 206, a laser module 209, a Temperature Sensor 212, a Monitor Photodiode 211 and a digital controller 213. The controller applies controls 204, 205 to signal the driver produce the appropriate magnitude of Modulation Current I_{Mod} 207 and Bias Current I_{Bias} 208. These currents are also shown in Figure 3, where the Laser Transmission Waveforms are illustrated. For

characteristic 101, the application of I_{Bias} 208 and I_{Mod} 207 results in Light Output-A 303. If however, the laser characteristic changes to 102 due to aging or temperature changes, the laser output will change to Light Output-B 302, which is of a substantially smaller magnitude and is not acceptable for many applications such as data transmission or analog signal transmission. There is the need to increase I_{Bias} 208 and I_{Mod} 207 in order to maintain the output constant. A way to compensate for the changes is to is to measure the change of the characteristic and make the appropriate corrections. Measurement poses a problem since many systems are required to be permanently on-line, transmitting data and cannot be interrupted to make a measurement of the new laser characteristic. The Monitor photodiode 211 is typically used to sense average power P_{AVE} 301, fast photodiodes are too costly for most applications and cannot be used to determine the change of the slope of the laser characteristic.

Description of the Prior Related Art

Various methods have been used in prior art to correct for the change in the laser characteristic. One method consists of creating a table of values for I_{Bias} 208 and I_{Mod} 207 versus temperature and having the Digital Controller 213 use a temperature sensor 212 to determine the magnitudes of the currents. This method however requires a costly process on the production line to heat the laser to generate the lookup table and cannot compensate for aging. This is because aging cannot be predicted ahead of time with the required level of precision to make a table of values.

Another method has been used in the past, which relies on the application of a tone signal that is applied to the laser. The tone is recovered by the monitor photodiode and the

recovered signal is used to determine the change of the laser. This approach has the disadvantage that the tone signal will disrupt the transmitted signal. Disruption causes a significant reduction of the noise margin, which renders the approach not useful.

Disadvantages of the industry practice:

◦No age compensation

◦Temperature sensor use is difficult and costly

–Mounting

–Calibration

–Correlation to laser temperature is poor

◦Costly to generate temperature compensation tables in manufacturing

◦Additional error caused by interpolation of temperature lookup tables

◦Devices and methods used to scale values of current have issues

–Commonly use additional hardware

–Not generally portable from one product generation to another

◦Additional IC used for Diagnostic Monitoring

SUMMARY OF THE INVENTION

The invention consists of mathematical models and an algorithm that compensates for aging, temperature linearity and other characteristics in a way that the transmitted signal is not affected. A synthesized test signal is applied to the laser system under test. The magnitude of the synthesized test signal is sufficiently small such that it is effectively buried in the noise of the system. Given that property, the synthesized test signal will not

change the noise margin of the transmitted signal or data.

Advantages of the present invention:

- ◦Closed loop precise and continuous Extinction Ratio and Optical Modulation Amplitude
- ◦Accurately determines laser parameters
- ◦Any temperature
- ◦Any age of the laser
- ◦Any transmission speed
- ◦Non-invasive
- ◦Close servo loop while data is transmitted
- ◦Saves power and space
  - –Laser bias and modulating current monitoring ICs become obsolete
  - –No temperature sensor circuits needed in uncooled laser applications

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1. Laser Characteristic Variation

Figure 2. Laser Control System Block Diagram

Figure 3. Laser Transmission Waveforms

Figure 4. Laser Performance Compensation Diagram

Figure 5. Laser Performance Compensation Process

Figure 6. Optical Transmission Link Performance Compensation

DETAILED DESCRIPTION OF AN EMBODIMENT

An embodiment of this invention is illustrated in the Laser Performance Compensation Diagram, Figure 4 (400). A DSP analyzer 410 implemented in firmware produces a synthesized test signal 411, which is applied to the DACs and drivers. An Adaptive Control System 401 implemented in firmware contains a Servo and it is used to set a given amount of laser power dependent on the laser characteristics. The servo is designed to utilize information in a configuration database regarding the laser characteristic and then adjust the light power to the correct value using those characteristics. The Adaptive Control System 401 directs the DACs and Drivers 402 to produce the correct amount of current 403, which is sent to the laser 404 to produce the desired light output 405. A monitor photodiode 406 is used to measure average power of the light output 405 and provide feedback to the Control System 401 to maintain the correct output. A signal conditioner 407 performs coarse filtering of the noise in the monitor photodiode 406 output in order to narrow the bandwidth and perform amplification of a band of the noise spectrum. The A/D converter digitizes the noise and the Firmware value scaler 409 accounts for calibration of the components used in the laser system. The DSP Analyzer 410 performs a detection algorithm to recover the synthesized test signal from the noise. Once the synthesized test signal is recovered, calculations of the slope efficiency of the laser characteristic along with the threshold inflection point are determined. The new values of the laser slope efficiency and inflection points are stored in the configuration database, which can then be used by the servo to adjust the light power to the correct value.

The Performance Compensation Process is illustrated in Figure 5. At 501 the Control path characteristic, which includes the Digital Controller, laser driver, laser, monitor photodiode, Signal Conditioner and A/D converter is calibrated.

The Controller applies a synthesized test signal 502 to the laser. A micro detector in the DSP analyzer 410 acquires the signal, which is buried in noise. In one embodiment, the DSP analyzer 410 utilizes a DSP algorithm 504 with lock-in detection to multiply a sinusoidal synthesized test signal by the digitized value resulting from the A/D conversion. The mathematical operation of multiplying two sinusoids in phase yields a DC value proportional to the amplitude of the two sinusoids divided by two, plus harmonics. The analyzer then applies an ultra low bandwidth low pass filter to eliminate the harmonics and noise. After the recovery of the synthesized test signal 502, the slope and threshold inflection point of the laser characteristic are determined and the updated parameters are passed on to the servo through the configuration memory. The servo then sets the laser output. Using the basic technique of injecting a micro level synthesized test signal comparable to the magnitude of the system noise opens a multiplicity of options for compensating a laser system. For example, other Digital Signal Processing (DSP) processes are possible which can be used to compensate for parameters such as linearity and wavelength tuning detection.

The present invention can be used to compensate for defects and changing characteristics of a fiber optic link while the link is in operation. As described in the references, this patent application is effectively a continuation in part of US 6, 446,867 titled "Electro-

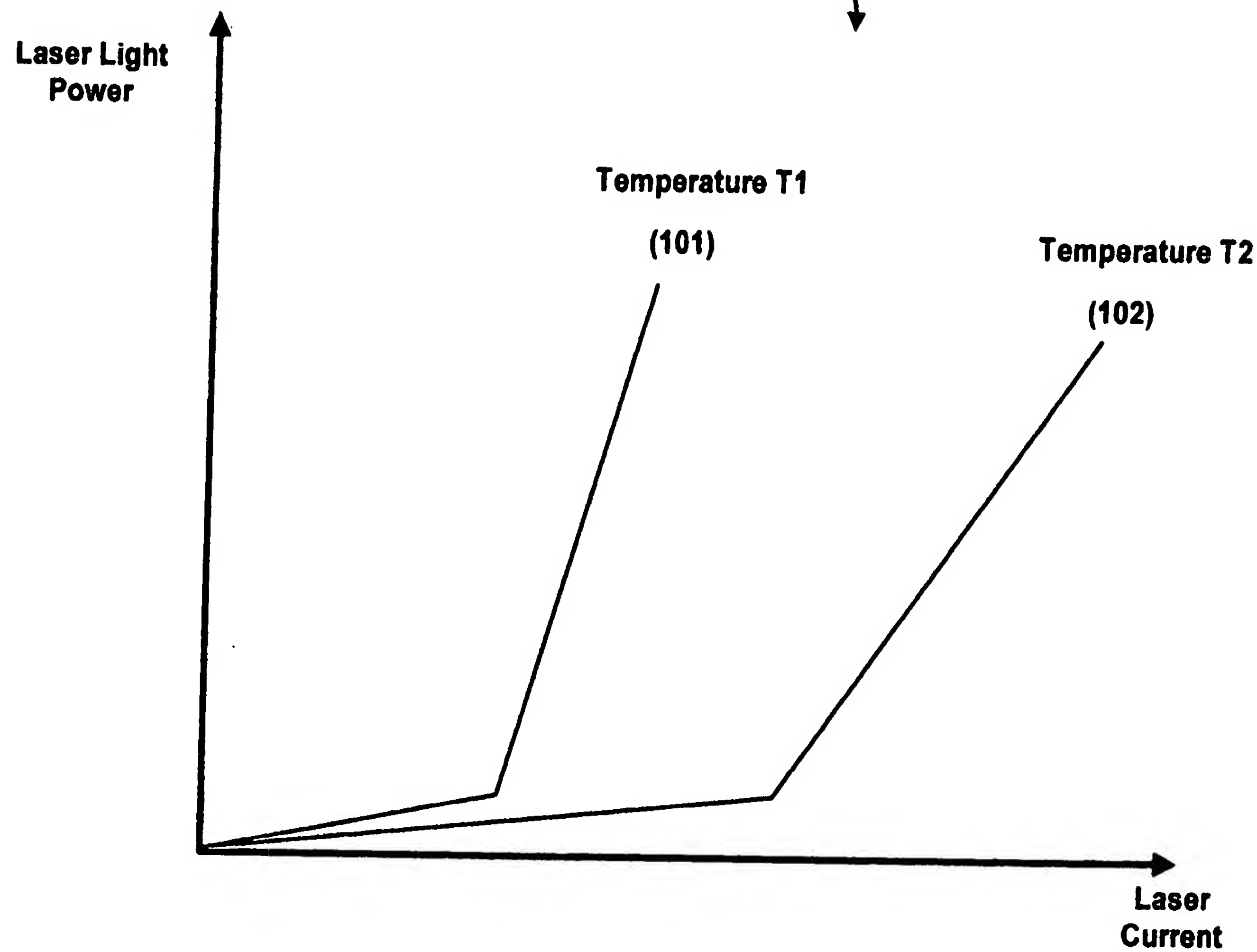
Optic Interface System and Method of Operation". US 6, 446, 867 describes a method used to calibrate a fiber optic link for various parameters using a Digital Controller and an internal switch in a transceiver used to close a loop in a fiber optic transmission system and thus recover information about the fiber optic link to perform necessary adjustment to the laser. Performance for the apparatus and method in US 6, 446, 867 can be enhanced by the use of the present invention for the purpose of link characterization since the fiber optic transmission system can now be characterized and adjusted while data is transmitted.

Optical Transmission Link Performance Characterization is shown in Figure 6. A first Transceiver 601 and a Second Transceiver 604 contain internally contain the hardware and firmware features described in Figure 4. Laser Performance Compensation Diagram 400. In addition, an appropriate internal architecture of the digital control as described in US 6, 446, 867 is contained. At 601, the First Transceiver control system injects a synthesized test signal, which will be embedded in the noise that is part of the light output of First Transceiver. The synthesized test signal travels through optical fiber 602 and is detected by Second Transceiver 604, where the signal is recovered by a signal processing method described above. The Digital Controller in Second Transceiver 604 detects the received synthesized through a lock-in detection measurement used to detect a signal buried in noise as described before. The information regarding the characteristic of the received signal is sent back to the First Transceiver 601 so that the laser in First Transceiver is adjusted to compensate for issues in the fiber optic link 602 in order to optimize signal transmission. The Second Transceiver 604 can send information regarding the measurement of the received signal back to the First Transceiver 601 by

using a similar technique as described before, i.e. a signal that is buried in noise ands having the First Transceiver 601 use a lock-in detection method. Information can be a digital signaling scheme, which uses a synthesized test signal of micro level magnitude as a carrier.

Figure 1. Laser Characteristic Variation

(100)



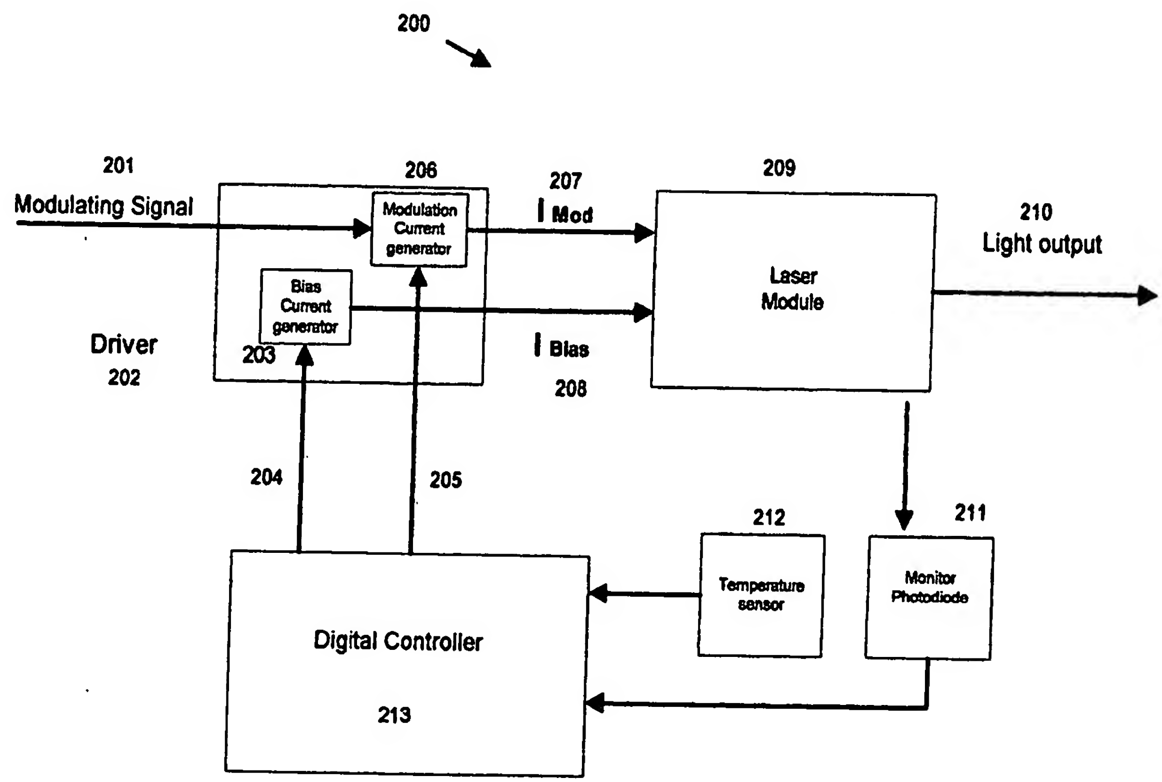


Figure 2. Laser Control System Block Diagram

Figure 3. Laser Transmission Waveforms

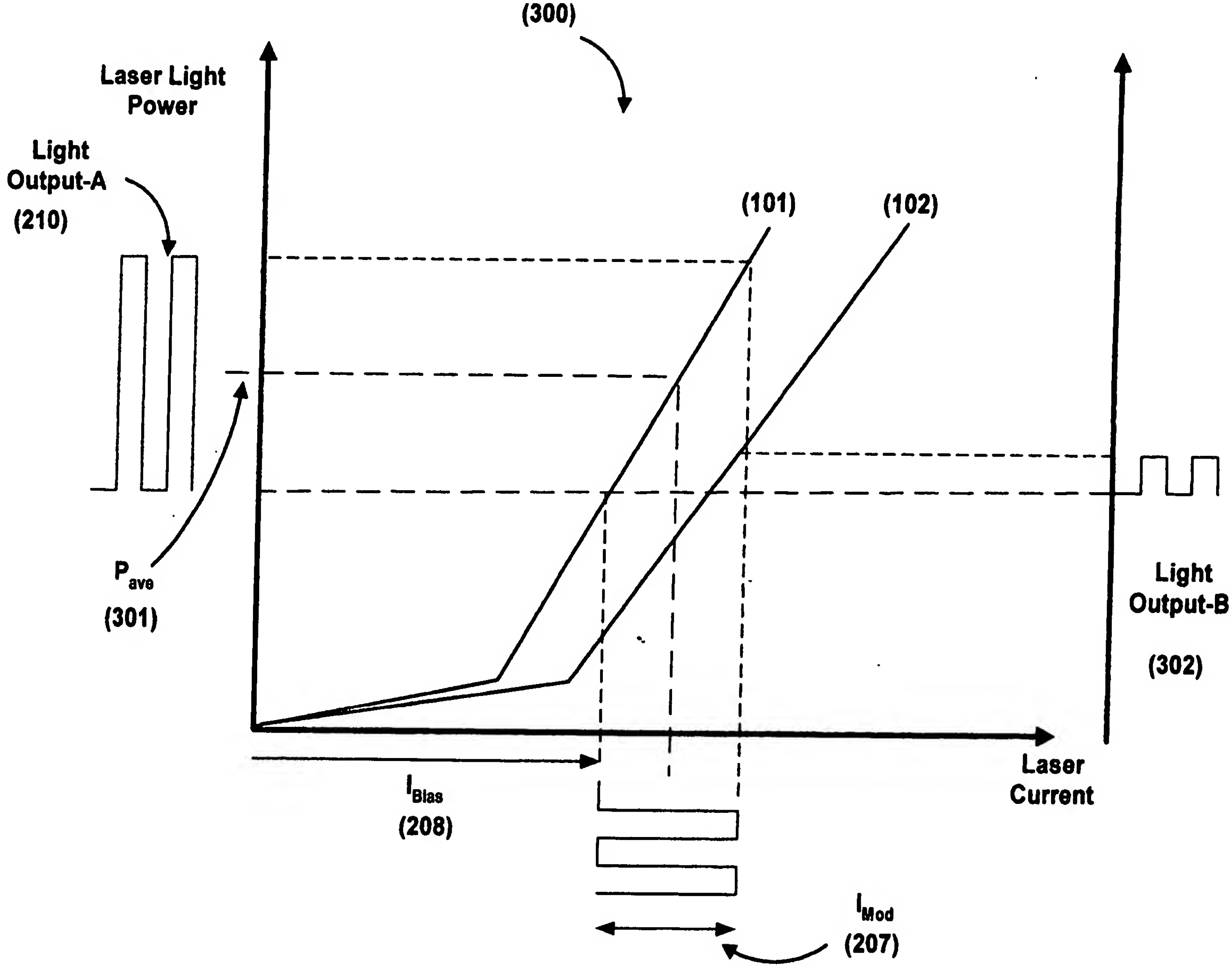


Figure 4. Laser Performance Compensation Diagram

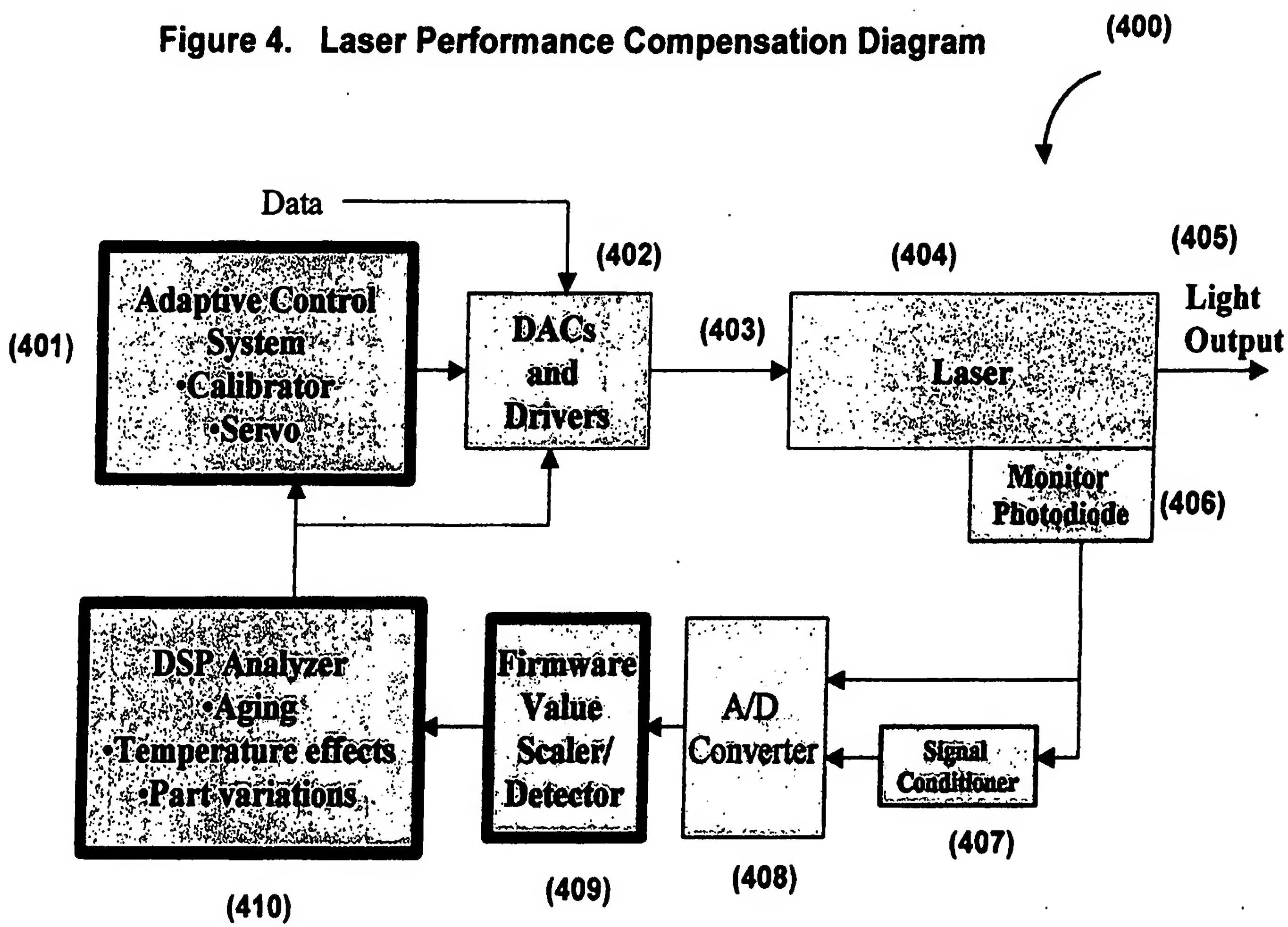


Figure 5. Laser Performance Compensation Process

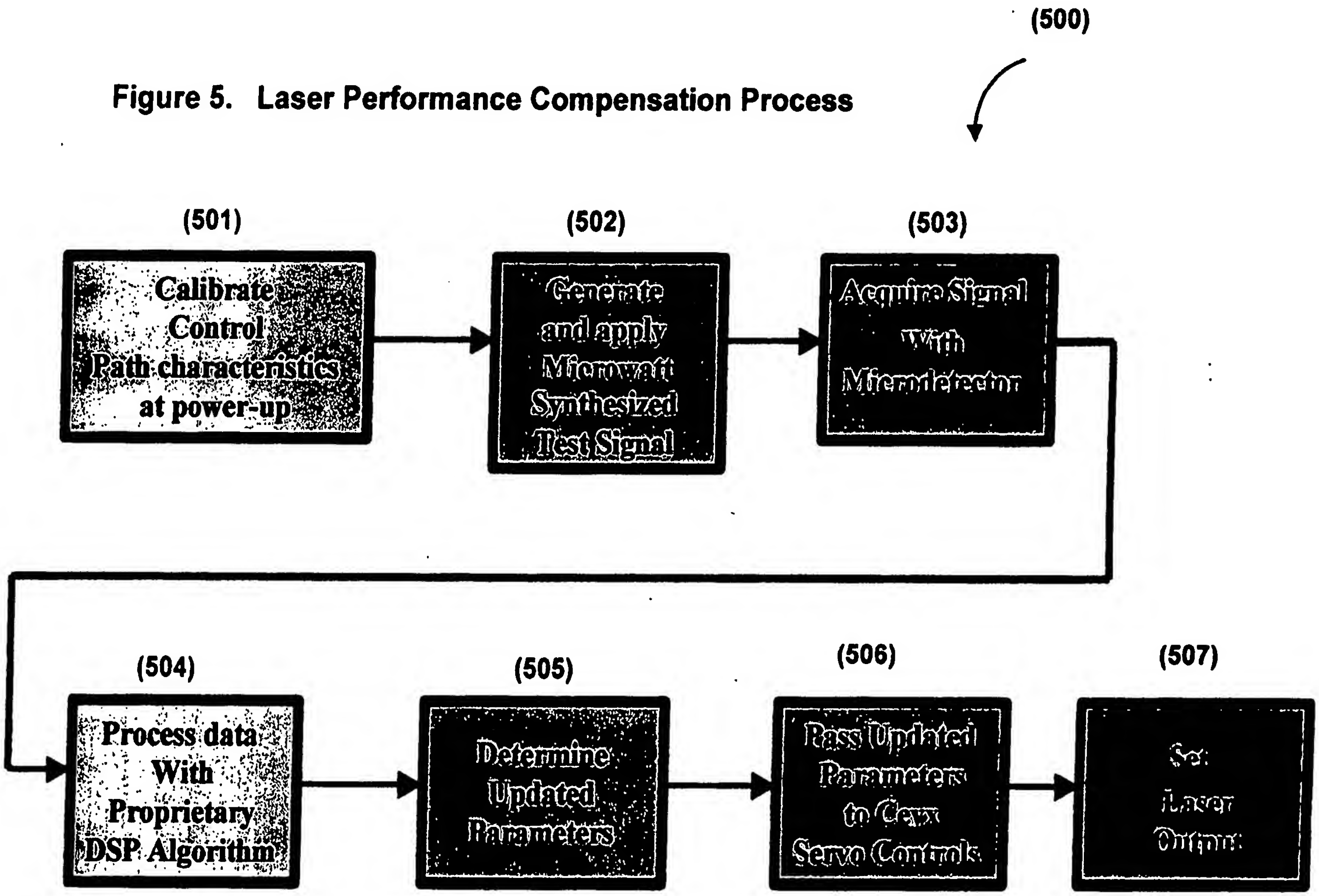
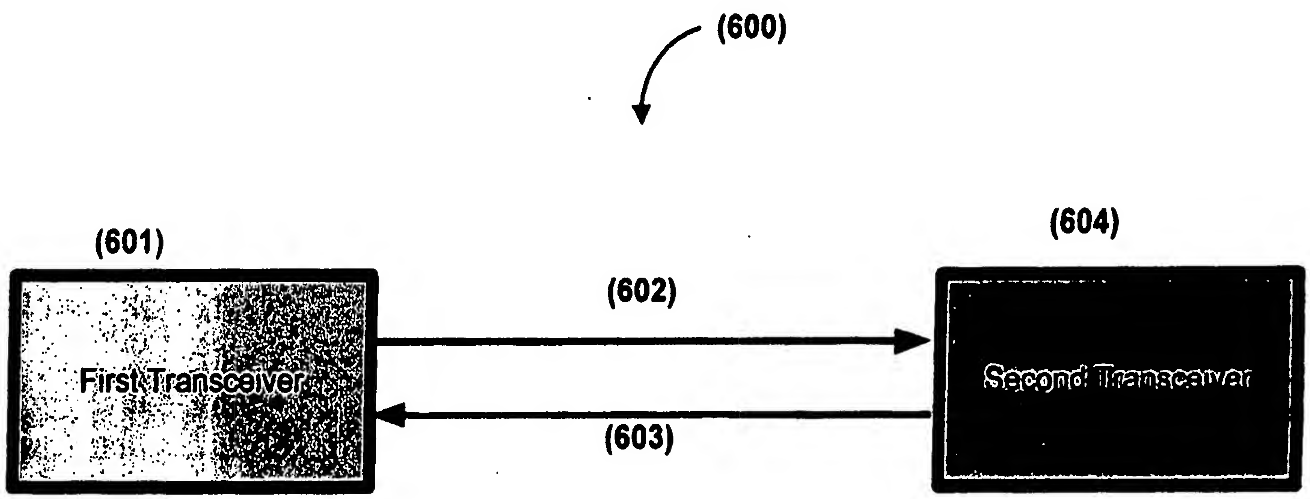


Figure 6. Optical Transmission Link Performance Compensation



Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/US05/013561

International filing date: 21 April 2005 (21.04.2005)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 60/564,143
Filing date: 21 April 2004 (21.04.2004)

Date of receipt at the International Bureau: 20 June 2005 (20.06.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

World Intellectual Property Organization (WIPO) - Geneva, Switzerland
Organisation Mondiale de la Propriété Intellectuelle (OMPI) - Genève, Suisse